Forest Health Protection

Pacific Southwest Region
Northeastern California Shared Service Area

Date: September 17, 2019
File Code: 3420

To: District Ranger, Hat Creek Ranger District, Lassen National Forest

Subject: Stand conditions with respect to forest insects and diseases within the Badger Project (FHP Report NE19-05)

Background

At the request of Jeff Durkin, Acting Silviculturist, Hat Creek Ranger District and Erin Hooten, Silviculturist, Enterprise Unit, Danny Cluck, Forest Health Protection (FHP) Entomologist, conducted a field evaluation of the Badger project area on August 29, 2019. This project area was also visited on June 23, 2017. The objective of these visits was to evaluate existing stand conditions, especially the high levels of recent white fir mortality. Treatment alternatives were discussed in the field and are documented in this report. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions aimed at reducing overall stand density with an emphasis on reducing the relative abundance of white fir.

Key Findings

- White fir abundance has increased within the mid to upper elevations of the project area due in large part to fire exclusion and augmented by past harvest of pine species. White fir is now the dominant conifer species in many stands that were historically pine dominated.
- Fir engraver beetle-caused white fir mortality has occurred at extremely high levels since 2015 (Figure 1). This has contributed course woody debris to the already existing high fuel loading from past mortality events over the past 26 years.
- The recent white fir mortality event followed similar drought related mortality events in the Badger project area (1987-1992, 2001-2004 and 2007-2009) highlighting unsustainable stand conditions.
- Many white fir that initially survived the 2012 Reading Fire in low severity burn areas sustained moderate to severe cambium injuries that have contributed to ongoing mortality and live tree failure.
- Overstocked native ponderosa pine stands have experienced elevated levels of tree mortality including large group kills caused by western pine beetle.

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- In addition to white fir mortality, mixed conifer stands within Badger project area have also experienced elevated levels of bark beetle-caused pine mortality (sugar, Jeffrey and ponderosa pine).
- Ponderosa and Jeffrey pine plantations are overstocked, and many have reached a susceptible size class that increases their risk to bark beetle attack.
- Thinning and prescribed fire are highly recommended throughout the project area to reduce tree density and surface and ladder fuel levels. Specific recommendations are provided in this evaluation.

Description of the project area

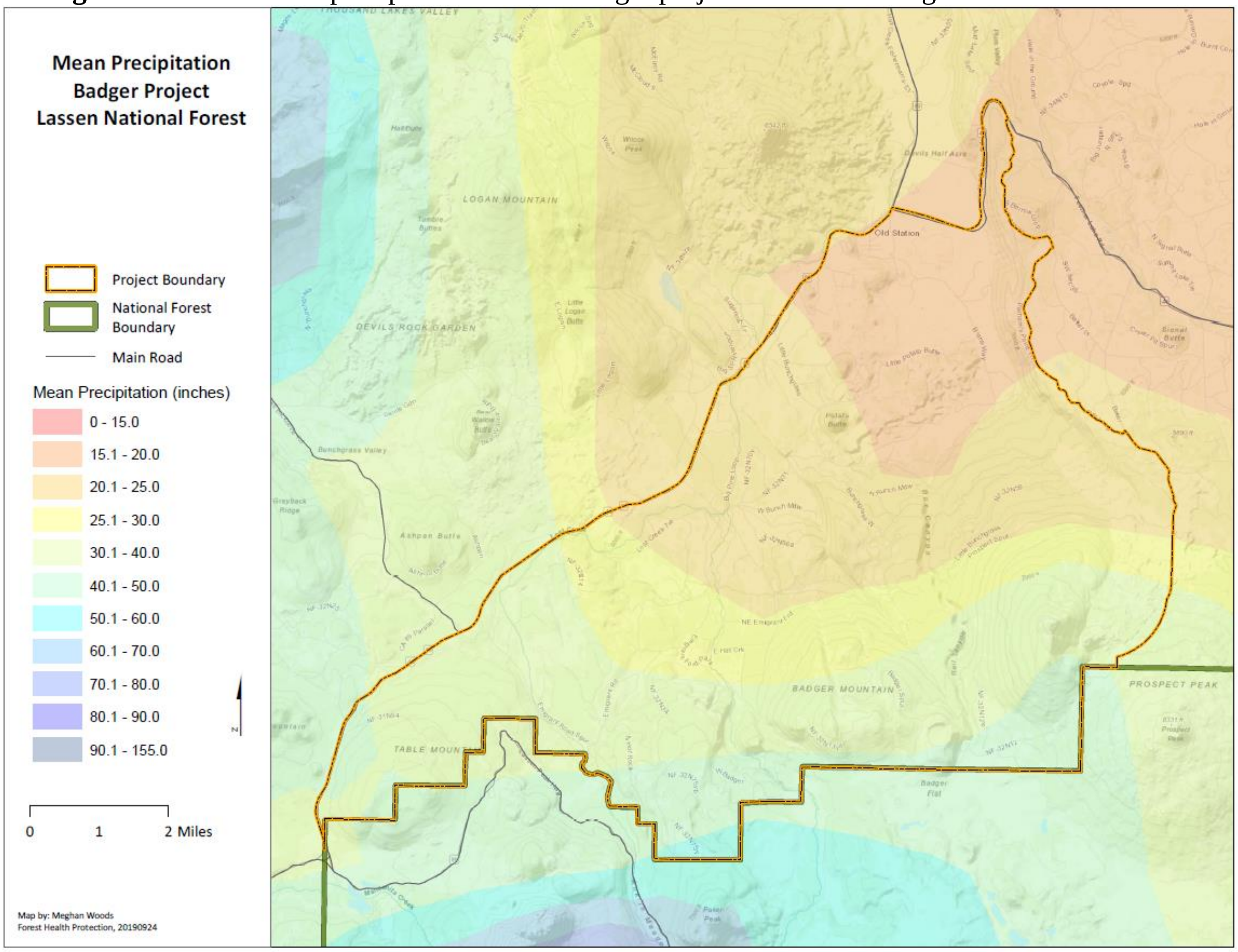
The Badger project is located on the Lassen National Forest and centered approximately 6 miles southwest of Old Station, CA (40.614791N and 121.455673W). The elevation ranges from 4,350 – 8,125 feet with annual precipitation between approximately 20 and 50 inches (Figure 2).

Figure 1. Dead and dying white fir west of Badger Mountain (2016 R5 ADS).

Forested areas range from eastside pine at lower elevations, predominantly ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*Pinus jeffreyi*), to mixed conifer with white fir (*Abies concolor*) being the dominant species. Jeffrey pine, ponderosa pine, lodgepole pine (*Pinus contorta var. murrayana*), sugar pine (*Pinus lambertiana*), red fir (*Abies magnifica*), Douglas-fir (*Psuedotsuga menziesii*) and incense cedar (*Calocedrus decurrens*) are all present in lower numbers. Pine species are found mostly in the mid and overstory layers as regeneration has been limited by the dense canopy cover of white fir. Much of the area was historically logged resulting in the removal of many overstory pines. This harvest activity combined with fire suppression has resulted in the current white fir dominated stand conditions. There are also several plantations, established in 1965, that are a mix of ponderosa and Jeffrey pine.

Most forested areas are densely stocked, have experienced elevated levels of tree mortality associated with insects, pathogens and drought and contain high numbers of standing and down dead trees, especially stands with a high percentage of white fir.

Figure 2. Mean annual precipitation for the Badger project and surrounding area.



Management objectives

The Badger project proposes to reduce fuels and improve forest health through thinning, mastication and prescribed burning. Stocking targets for all stands will aim to reduce susceptibility to bark beetles and reduce the relative abundance of white fir. Residual stands will be more open, increasing the amount of available soil moisture and sunlight for individual trees. Specifically, restoration treatments designed to create resilient forest conditions will be guided by Natural Range of Variability (NRV)

- Increase forest heterogeneity
- Reduce tree densities
- Retain large, old trees and snags
- Restore proportion and distribution of tree species consistent with NRV
- Restore amount and distribution of duff, litter, and woody debris
- Restore natural disturbance regimes
- Manage highly-disturbed areas for NRV

Forest insect and disease conditions

Bark beetle activity observed during the site visit was primarily in white fir where fir engraver beetle (*Scolytus ventralis*) has recently caused very high levels of tree mortality throughout the project area. Depending on location, white fir mortality was also associated with Heterobasidion root disease (caused by *Heterobasidion occidentale,* formerly referred to as S-type annosus root disease) and fire-injuries sustained during the 2012 Reading Fire (Figure 3). Heterobasidion root disease in true fir is especially severe along the Highway 44 corridor from just east of Ashpan Snowmobile Park to the north entrance to Lassen Volcanic NP.

Figure 3. White fir mortality outside of fire perimeter west of Badger mountain along 32N75Y road (2016 R5 ADS).

Western pine beetle (*Dendroctonus brevicomis*)-caused mortality of a ponderosa pine was observed in 2017 at the base of West Prospect Peak (Figure 4) and along the 32N12 road on the north side of Badger Mountain. The area along the 32N12 road contained several large group kills of approximately 25 trees each.

White pine blister rust (*Cronartium ribicola*) in combination with mountain pine beetle (*Dendroctonus ponderosae*) was found in sugar pine causing scattered top-kill and whole tree mortality on West Prospect Peak (Figure 4).

Western dwarf mistletoe (*Arceuthobium campylopodum*) and elytroderma disease (*Elytroderma deformans*) in Jeffrey and ponderosa pine were observed in several locations throughout the project area. Elytroderma was prevalent within some plantations and along Highway 44 near Eskimo Hill Summit causing branch brooming and stem deformities.

A few old growth Jeffrey pines have been killed by Jeffrey pine beetle (*Dendroctonus jeffreyi*) in the northwest portion of the project area since 2015.

Aerial detection surveys (ADS) have mapped ongoing high levels of white fir mortality caused by fir engraver beetle throughout the project area for the past 5 years. The highest levels were mapped in 2015 and 2016 during the peak of the drought.

Figure 4. Scattered mortality of sugar pine, ponderosa pine and white fir in mixed conifer area on West Prospect Peak (2016 R5 ADS).

Stand conditions and mortality related to recent and future climate trends

Most of the forested areas in the Badger project area are in an overstocked condition and have experienced an elevated level of tree mortality caused by bark beetles during and since the recent drought. Forest Health Protection Aerial Detection Surveys mapped large areas of tree mortality, especially white fir, within the project area in 2018 (Figure 5) and have continuously mapped tree mortality between 2009 and 2018 (Figures 6 and 7 and Table 1). Elevated levels of bark beetle-caused tree mortality within the project area are strongly associated with periods of below normal precipitation and high stand density. The abundance of white fir has amplified these conditions and resulting in extremely high levels of tree mortality and subsequent fuel loading.

Most stands have experienced a species composition shift from shade intolerant ponderosa and Jeffrey pine to more shade tolerant white fir in the absence of fire (Figure 8). White fir is now abundant on many sites that are considered medium to high risk for mortality during drought periods (based on average annual precipitation, see pages 8 and 9). The mortality resulting from the recent drought as well as previous droughts provides ample proof that most Badger project areas do not support healthy stands of white fir over the long-term. Even white fir growing in more mesic mixed conifer sites have sustained high levels of mortality.

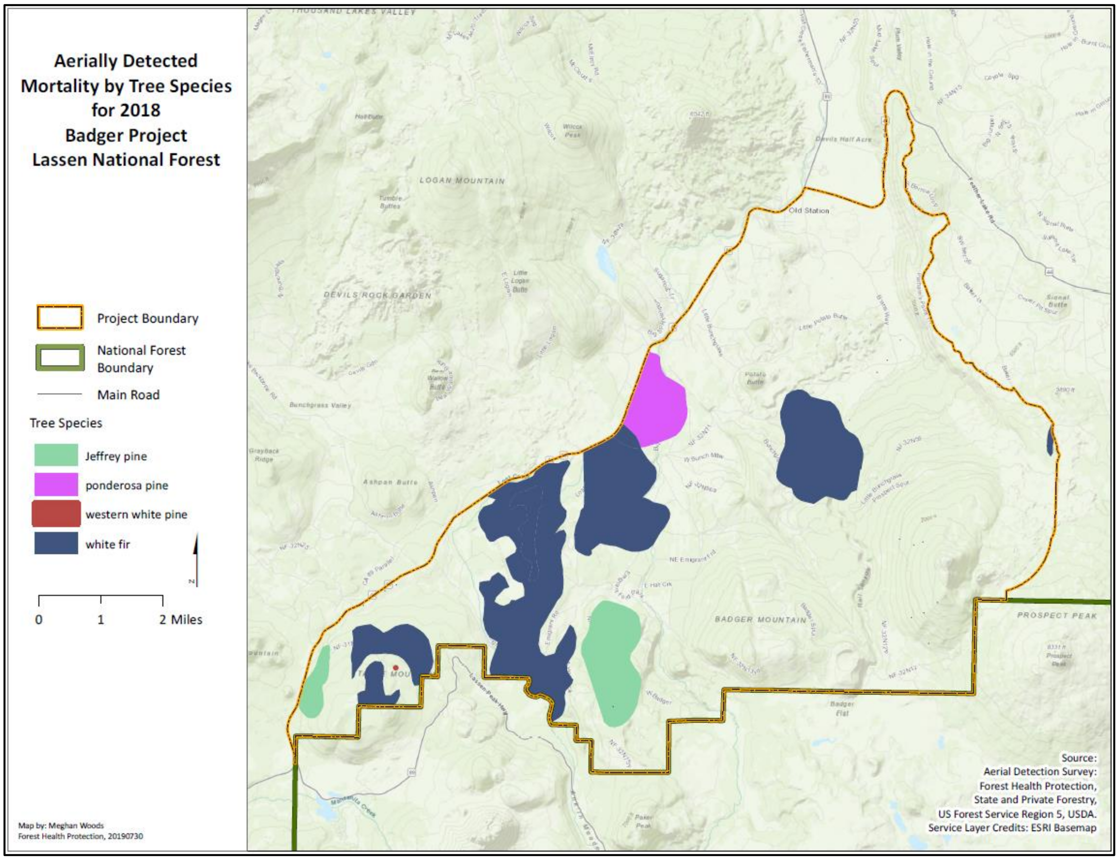


Figure 5. Extent of white fir and other conifer mortality in 2018 as detected by ADS flight.

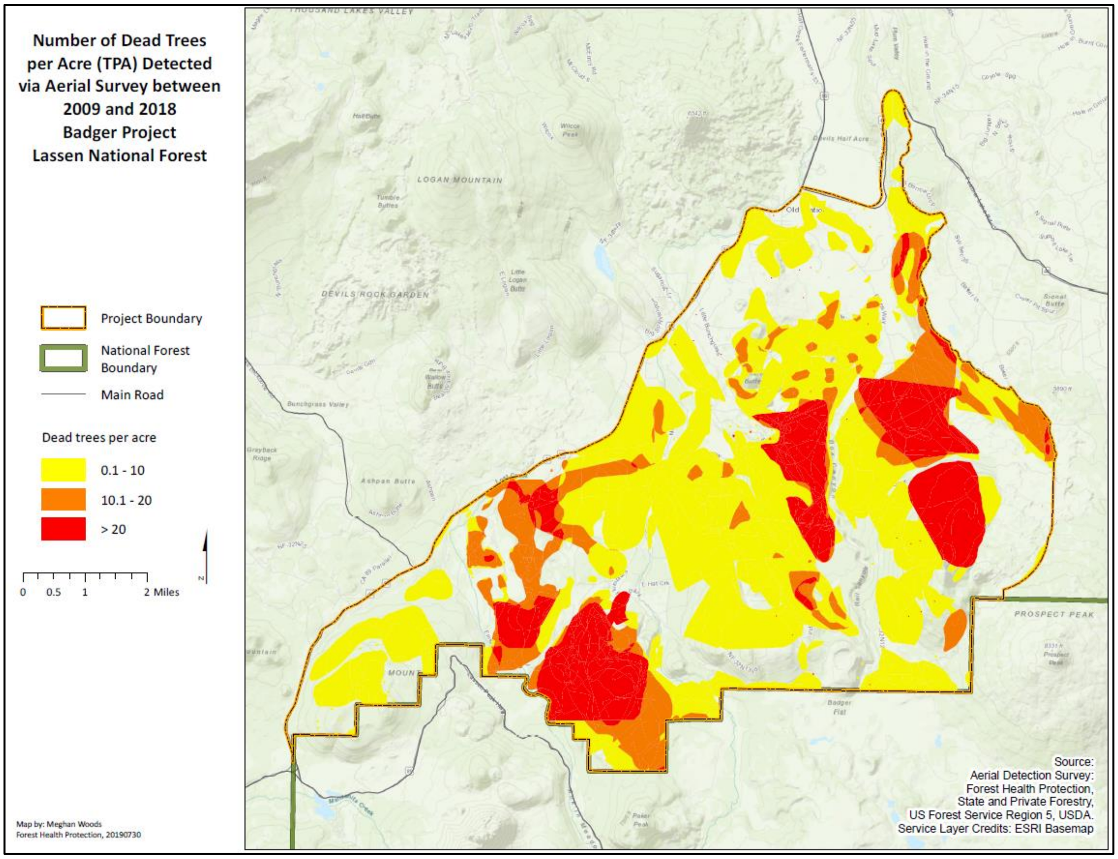


Figure 6. Number of dead trees per acre mapped by ADS from 2009 to 2018.

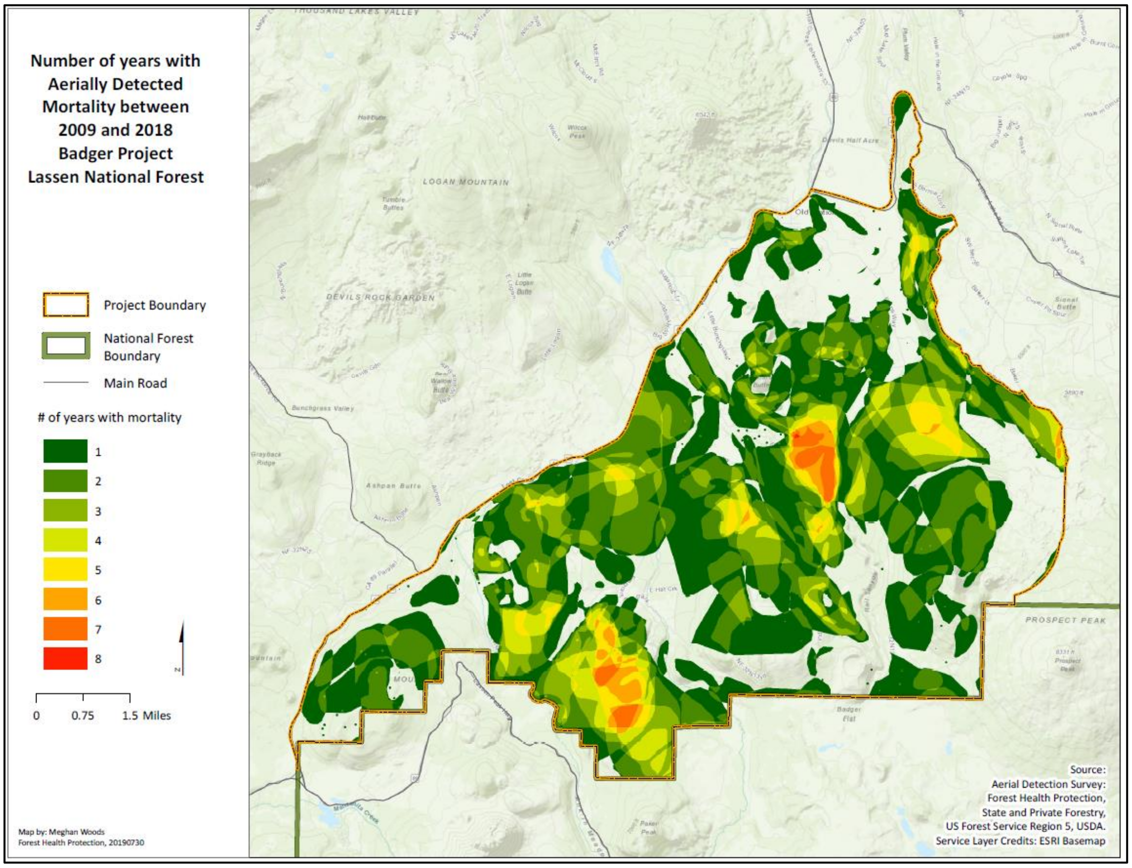


Figure 7. Number of years with elevated tree mortality mapped by ADS between 2009 and 2018.

Table 1. Acres with mortality, estimated dead trees per acre and estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (average of CA Divisions 2 and 3[1]) by water year (Oct-Sept) within the Badger project area.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI[2]
2018	7,403	5.0	37,037	-0.82
2017	8,425	5.6	46,937	3.03
2016	10,142	7.4	75,056	-1.32
2015	7,060	11.2	79,261	-3.34
2014*	1,196	3.2	3,841	-3.56
2013*	709	3.2	2,274	-2.16
2012*	1,789	1.6	2,840	-0.59
2011	6,203	2.9	18,205	2.78
2010	17,941	6.1	108,869	-0.14
2009	7,189	2.4	17,073	-2.98

[1] California Divisions 2 and 3 encompass most of northeastern California.

[2] PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

*Tree mortality not mapped within Reading Fire perimeter during 2012, 2013 and 2014.

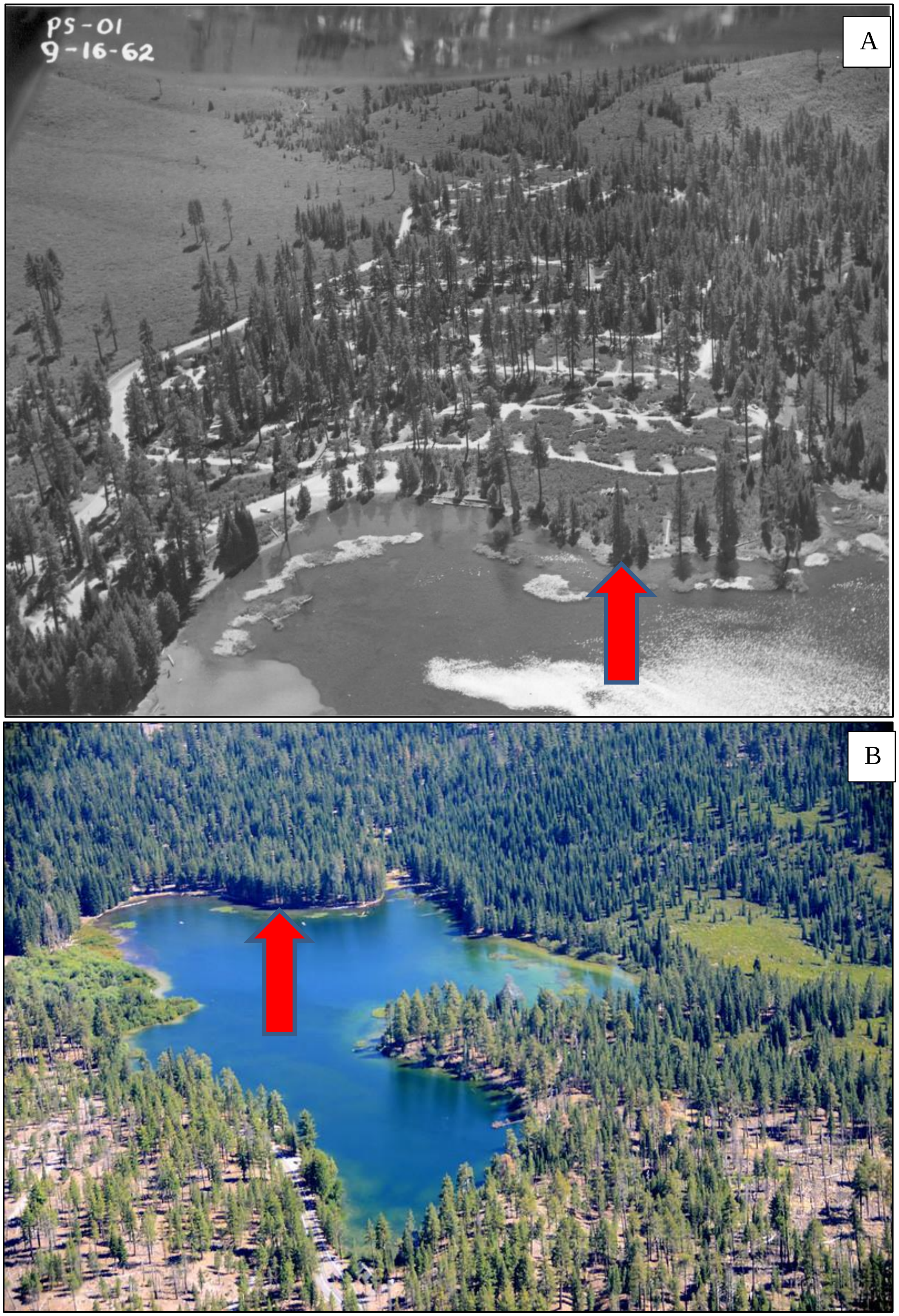


Figure 8. Example of the increase in white fir at Manzanita Lake, CA (Lassen Volcanic NP), adjacent to west side of Badger project. Photo A taken in 1962 and photo B taken in 2015 (red arrows indicate identical reference points).

White fir that succumb to fir engraver beetle attacks are typically predisposed by other factors that compromise their health and vigor. In the Badger project area, high stand density, prolonged drought, trees growing off site, fire-injury and Heterobasidion root disease are all contributing factors in declining tree health and mortality.

The distribution of both white fir and white fir mortality are strongly influenced by the mean annual precipitation. The lower limit of precipitation in the natural range of white fir is about 20 inches (Fowels, H.A. 1965). The isohyetal map of mean annual precipitation provided in this report (Figure 2) can be used to rate the risk of white fir mortality (Schultz 1994).

<u>Low risk: 40+ inches annual precipitation **(~10% of Badger Project**).</u> These areas easily support stands of white fir. Mortality will be low, even during drought periods. Thinning will increase the rate of tree growth, but will show only slight differences in tree mortality.

<u>Medium Risk: 30-40 inches of annual precipitation **(~25% of Badger Project**).</u> Stands in these areas often have a high percentage of white fir that may achieve a considerable age and size. Prolonged drought may cause mortality of 5-10% of the stems. Periodic thinning which concentrates on removing white fir ingrowth will lower mortality by maintaining a more sustainable amount of biomass, as well as promoting a more stable mixed species stand.

<u>High Risk: 25-30 inches of annual precipitation **(~15% of Badger Project**).</u> In the absence of fire, these areas have stands which are dominated by densely stocked, small diameter white fir. The species distribution by age class shows an increase in the relative percentage of white fir in these stands following fire suppression. Prolonged drought may cause mortality in excess of 50% of the stems. The risk of mortality can be lowered by thinning to a wide spacing prior to the onset of drought, and by promoting a mix of species that are native to the site.

<u>Extreme risk: <25 inches of annual precipitation **(~50% of Badger Project**).</u> In some cases, the shade tolerant trees may live long enough to achieve an intermediate or co-dominant crown position. Prolonged drought may cause mortality of 80-85% of the stems. In stands where the total stocking of both overstory and understory is high, mortality may also occur in the pines. The risk of mortality may be lowered by managing groups of pine at wide spacing.

Approximately 65% of the project area receives less than 30 inches of annual precipitation. Thirty inches is below what is generally required for healthy white fir forests to exist over the long-term. Therefore, even at the lowest stocking levels, white fir growing on these sites are at a high to extreme risk for fir engraver beetle-caused mortality during periods of drought. Even in stands that receive between 30 and 40 inches, the risk of mortality during drought is still considered medium. For the Badger project area, areas that are at medium risk have experienced very high levels of mortality during recent droughts and this should be considered when developing thinning prescriptions.

A white fir levels of growing stock study conducted by Cochran (1998) on the Deschutes and Fremont National Forests between 1983 and 1995 provides some additional information to consider when managing white fir in lower precipitation areas. Plots were thinned in 1982 and again in 1985 to a residual stand density index (SDI) of 112, 168, 224 or 280. These corresponded to growing stock levels of 20, 30, 40 or 50 percent of normal density. Elevations for his study plots ranged from 4,500 to 5,900 feet with average annual precipitation ranging from 16 to 31 inches. A general drought prevailed over the study areas from the late 1970's to

the mid 1990's and mortality between 1991 and 1995 destroyed the study. Mortality on Blocks 2, 3 and 4 of the study was attributed to fir engraver beetles. Mortality from fir engraver beetles appeared to increase with increasing stand densities and was above acceptable levels even at the lowest stand density (20 percent of density considered normal for white fir).

From Cochran 1998: "Healthy stands of white fir grow very rapidly, produce a dense crown cover, and are visually pleasing. These results, however, raise doubts about growing white fir stands on sites with mean annual precipitation rates below 32 inches even if stand densities are kept very low. The four widely scattered stands represented in this study apparently grew well for more than 60 years and reached commercial size before severe mortality occurred. Where significant amounts of white fir are present, managers need the ability to manipulate stand composition to minimize mortality. Future stands on similar sites should have a large component of ponderosa pine and should be managed by using ponderosa pine stocking guides (Cochran and others 1994). These density levels would allow the individual fir trees, intermingled with pine, to reach commercial size at fairly young ages. If drought, disease outbreaks, or severe insect infestations occur, the white fir could be removed, leaving ponderosa pine on the site. Ponderosa pine quickly responds to new growing space even at old ages and would quickly take advantage of the available site resources. Ferrell (1978) reports that trees under high moisture stress (-20 bars dawn xylem pressure or higher negative pressures) for protracted summer periods are more susceptible to successful fir engraver attacks than are trees under less stress. If prolonged droughts are forecast, removal of most of the white fir on drier sites may be advisable. This would prevent the buildup of fir engraver populations that could migrate to moist sites and inflict heavy damage where, historically, white fir has survived dry periods."

In a Warner Mountain study by Egan et al (2010), the density of fir engraver beetle-caused tree mortality was greater in unthinned versus thinned mixed conifer stands but the percentage of mortality relative to available host trees was similar. This further suggests that white fir growing in high risk sites (based on average annual precipitation) are susceptible to drought and fir engraver-beetle caused mortality regardless of stocking levels.

From Egan et al (2010): "Our findings varied in mixed conifer areas as the density of, but not percent, FEN (fir engraver beetle)-caused mortality was reduced in thinned areas. These results do not support the use of thinning to reduce percent mortality or the relative number of residual white fir trees susceptible to FEN-caused mortality during times of drought. Conversely, this study does support the efficacy of thinning to reduce the density of mortality or absolute number of beetle-killed trees in mixed conifer stands exposed to drought conditions. The density of residual white fir host and elevation (likely a proxy for water availability) were important factors associated with white fir mortality in our study. These findings indicate thinning effectiveness in reducing fir mortality was directly proportional to the amount of post-treatment density white fir retained. Thus, our findings support discriminating against residual fir and retaining a greater pine component, similar to historic compositions (Vale, 1977), during thinning treatments to reduce the density of FEN-caused mortality even during periods of drought."

Several Forest Health Protection reports since 1994 have also identified unhealthy white fir stand conditions on northeastern California forests and the need for thinning (FHP reports available upon request). Most of these reports concurred that without treatment, the trend for most stands of increasing stand density, high levels of insect and disease activity and elevated levels of tree mortality would likely continue until a major disturbance event such as a stand replacing fire occurred. Schultz (1994) recommended thinning white fir stands on the Big Valley RD, Modoc

NF, to manage for pine as a more sustainable stand structure; stating, "Unless these areas are being managed for habitat for a species which is dependent on small diameter dead white fir, or there is an economic market for small diameter white fir, then it would promote a more sustainable stand structure to manage for pine."

Forest Health Protection recently developed a treatment priority map for Region 5 to help land managers prioritize thinning treatments at the landscape level. This map depicts forested areas on National Forest System lands that are the most susceptible to drought and bark beetle-caused tree mortality based on forest type, average tree diameter and stand density. These areas also meet the criteria of existing on slopes <=35% and being outside of wilderness areas, wild and scenic river corridors and designated roadless areas. Additional criteria include not having burned at moderate to high severity since 1998 and not having been thinned since 2005. In addition to being overly dense, these areas have a history of tree mortality during drought resulting in heavy fuel loads and higher risk of stand replacing wildfire. Highest priority areas consist of high-density pine stands, pine-dominated mixed conifer stands, and fir-dominated mixed conifer and white fir stands growing on historically pine dominated sites. Second priority areas consist of high-density fir-dominated mixed conifer and white fir stands on wetter sites. All mapped stands are California Wildlife Habitat Relationship size class 4, 5 and 6.

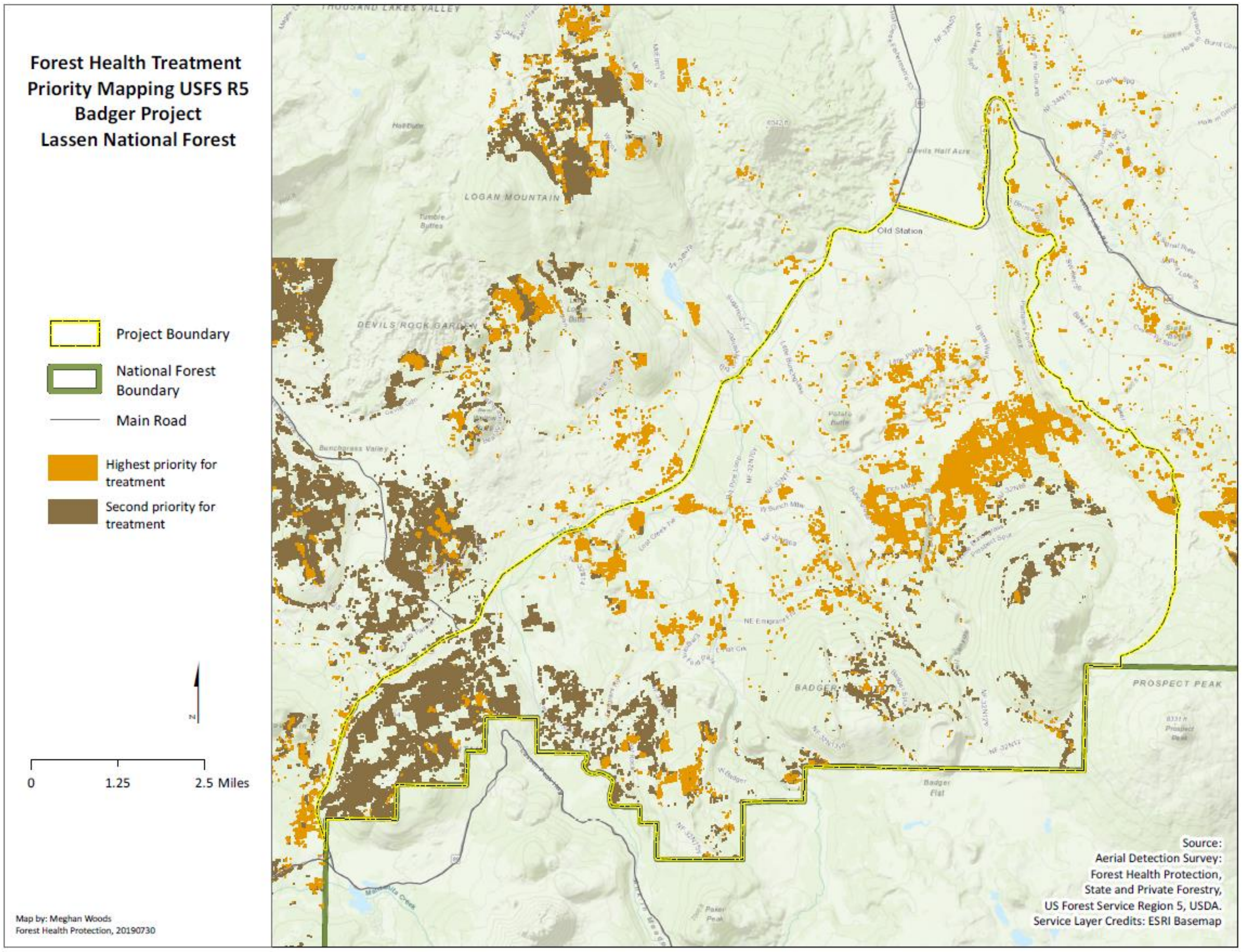
Figure 9 shows treatment priority areas within the Badger project boundary. This mapping effort utilized remotely sensed data to create treatment priority layers for large scale planning and may not be accurate at the stand level. The forest should still use stand records and stand exam data to identify treatment areas and develop silvicultural prescriptions. An ALL LANDS version of the map was also created that includes wilderness areas, wild and scenic river corridors designated and roadless areas to evaluate stand conditions in these protected areas. It also includes all land ownerships (Figure 10).

Predicted climate change is likely to impact trees growing in the Badger project area over the next 100 years. Although no Lassen National Forest specific climate change models are available at this time, there is a consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and Lassen National Forests*. The risk of bark beetle-caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

Considerations for thinning treatments

Most mixed conifer stands within the Badger project should be managed for the pine component as much as possible. This includes all white fir dominated stands with a ponderosa/Jeffrey pine component. This will likely require a change from the current mixed conifer or white fir stand typing in many areas to yellow or eastside pine, better representing historic species compositions and desired future conditions. Having the ability to significantly reduce stand density and the abundance of white fir is critical to successful ecological restoration within the project area.

Figure 9. Treatment Priority Areas* at risk to bark beetle-caused mortality within and adjacent to the Badger project area

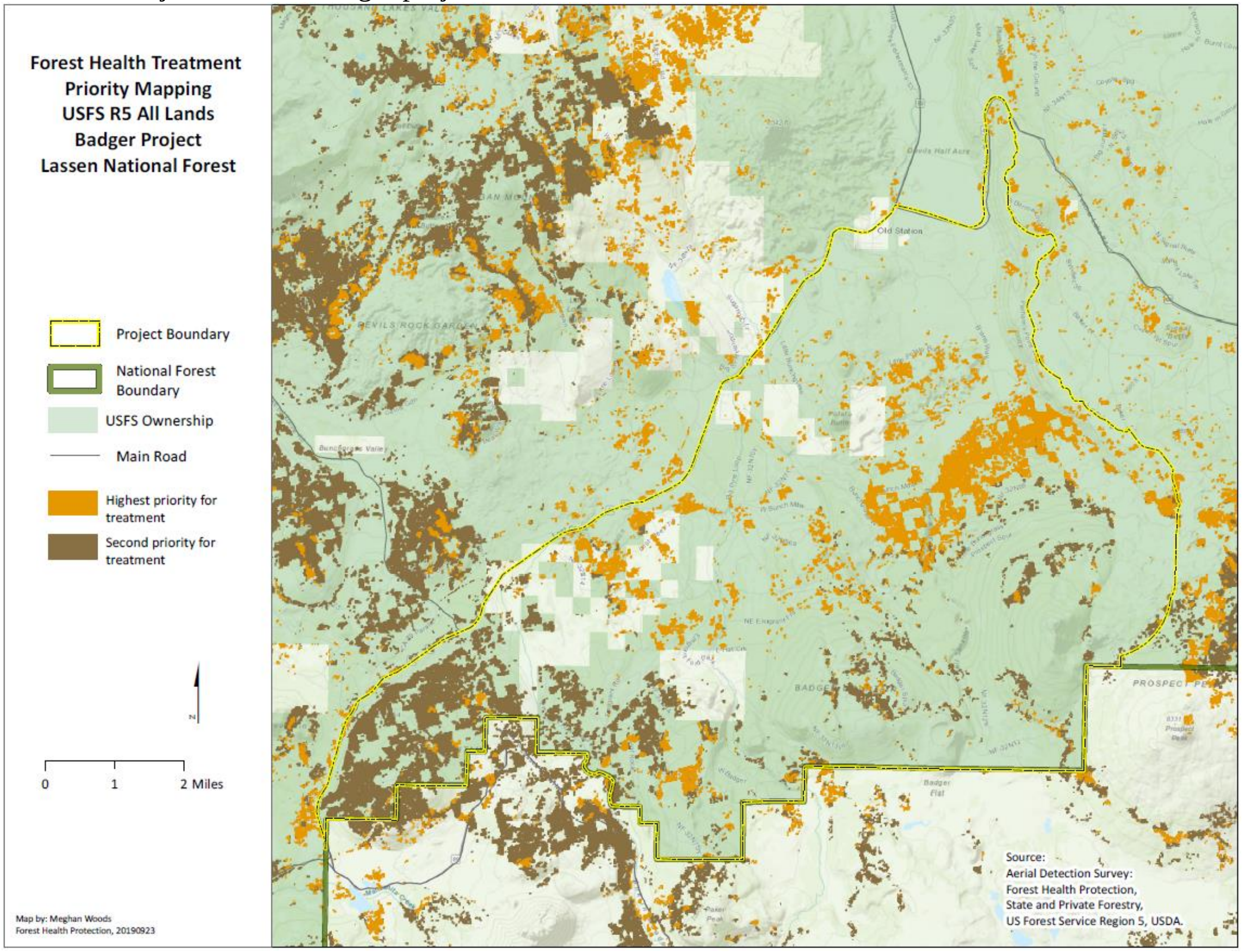


*Highest priority treatment areas include overly dense stands (>60% of maximum stand density index) of pine and pine-dominated mixed conifer stands as well as fir-dominated mixed conifer and white fir stands growing on historically pine-dominated sites. Second priority treatment areas include overly dense stands of fir-dominated mixed conifer and white fir. Mapped areas only include CWHR size class 4, 5 and 6 stands. Wilderness areas, inventoried roadless areas, wild and scenic areas, moderate to high severity burned areas since 1998, areas thinned since 2005, areas with >35% slope and all non-National Forest System lands were excluded from this analysis.

Thinning stands without significantly reducing stocking levels and the abundance of white fir will not likely result in a change in trajectory towards a pine dominated fire-adapted condition. A high residual component of white fir will continue to produce abundant seed, increasing the number of white fir seedlings relative to pine seedlings. Subsequent and frequent prescribed fire can help change the trajectory of seedling establishment towards pine, but its use is often hampered by lack of appropriate burning conditions, air quality concerns or adequate resources for implementation. Even if prescribed burning is accomplished, is not likely to significantly reduce the number of larger diameter, seed producing white fir in thinned stands due to generally thicker bark and higher crown base heights.

When planning thinning treatments, it should be recognized that the target stand density and species composition is an average to be applied across the landscape and some variability may be desired to increase heterogeneity. Individual high-value trees, such as mature pines, and drier areas dominated by ponderosa/Jeffrey pine should benefit by having the stocking reduced to

Figure 10. Treatment Priority Areas (ALL LANDS version)* at risk to bark beetle-caused mortality within and adjacent to the Badger project area.



*Highest priority treatment areas for ALL LANDS version include overly dense stands (>60% of maximum stand density index) of pine and pine-dominated mixed conifer stands as well as fir-dominated mixed conifer and white fir stands growing on historically pine-dominated sites. Second priority treatment areas include overly dense stands of fir-dominated mixed conifer and white fir. Mapped areas only include CWHR size class 4, 5 and 6 stands. Moderate to high severity burned areas since 1998, and areas thinned or that experienced stand replacing disturbance such as clear cuts or bark beetle-caused tree mortality since 2005 were excluded from this analysis.

lower levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees. Higher concentrations of white fir can be retained at higher elevations that receive >30” average annual precipitation. Tree removal should include trees heavily infected with dwarf mistletoe, root disease and trees infested with bark beetles. Small group harvest could also be utilized to remove white fir that are within known Heterobasidion root disease centers or are heavily infested with dwarf mistletoe. This would create openings that could be planted with sugar, ponderosa and Jeffrey pine.

In most cases, thinning to a relative density of 25 - 40% (relative to the maximum Stand Density Index, or SDI) for a specific conifer species or for a weighted composition of conifer species will effectively reduce competition for limited water and nutrients and reduce the susceptibility to future bark beetle-caused tree mortality. This approach will also increase the longevity of treatments as they should stay below 60% relative density, the general threshold for self-thinning, for many years. For the Badger project area, the District should consider basing relative density targets on the pine component of most mixed conifer and white fir stands. A possible

target could be a maximum stand density index of 450 for ponderosa pine as suggested by Long and Shaw 2005. In areas where white fir will remain the dominant stand component, due to more favorable site conditions for the species, a maximum stand density index of 550 as described by Long and Shaw (2012) may be appropriate.

The latest peer-reviewed research on Jeffrey pine stocking as it relates to Jeffrey pine beetle-caused mortality (Egan et al 2016) and a FHP report for the same study (Egan et al 2009) suggest stocking levels that are at or below SDI 210 (corresponded to < 125 sq.ft./acre of basal area in study plots) to reduce tree mortality during droughts and high bark beetle population pressure. Stocking levels of SDI 110 (corresponded to <80 sq.ft./acre of basal area in study plots) had no Jeffrey pine beetle-caused mortality during the Jeffrey pine beetle outbreak monitored during the study. These stocking guidelines are also appropriate for ponderosa pine (Oliver 1995).

Many stands contain large diameter ponderosa, Jeffrey and sugar pine. Thinning treatments that improve growing conditions for these more shade intolerant species, such as removing a large percentage of the white fir basal area around these trees, would increase their health and vigor, create opportunities for their successful regeneration and improve overall resiliency to disturbance agents (insects, disease, drought and fire). Removing competing trees from the base of large diameter pines combined with stand level thinning has resulted in a measured increase in annual increment growth in old growth ponderosa and Jeffrey pine on the Lassen National Forest (Hood et al 2017). Monitoring of treatments around sugar pines in Oregon revealed a large increase in sugar pine regeneration (Schaupp et al 2018).

When thinning out competing conifers from the base of large sugar pines, it is recommended that a least a few trees and/or brush be retained for soil shading within the root zone. Preliminary results from monitoring in Region 6 suggest that complete clearing of competing conifers from the base of large diameter sugar pine may not enhance survival of treated trees and might even contribute to tree stress and subsequent mortality due to excessive heating and drying of soil (Schaupp et al 2018).

The presence of Heterobasidion root disease in true fir, especially white fir, should be considered when developing silvicultural prescriptions. Root diseased true fir are at a higher risk for fir engraver attacks than uninfected trees during droughts. Leaving high numbers of root diseased trees will likely lead to higher levels of mortality over the long-term, reducing large tree canopy cover and increasing fuels. Leaving these trees will also reduce opportunities for successful regeneration of shade intolerant species that are not susceptible hosts to *H. occidentale*.

The best option for managing *H. occidentale* in white fir is to reduce its overall abundance in the stand and remove severely infected trees. Various sized openings can be created in the stand to facilitate planting of non-hosts such as ponderosa and Jeffrey pine. Placing these openings on known or suspected root disease pockets will enhance the effectiveness of this strategy for reducing overall infection levels. In addition, greatly reducing white fir stocking in stands that have a non-host overstory component will allow for natural non-host regeneration and create a more resilient species composition over time.

It is recommended that a registered borate compound be applied to all freshly cut conifer stumps >14” in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *H. occidentale* formerly referred to as P-type and S-type annosus root disease, through harvest activity. An exception to this recommendation would be treating white fir

stumps in mixed conifer, pine/white fir or more pure white fir stands if there is already a high level of Heterobasidion root disease present as treating white fir stumps in heavily infected stands is ineffective.

Considerations for Rx fire

If prescribed fire is used as a follow-up treatment to stand thinning or as a standalone treatment, unacceptable levels of large diameter pine mortality may occur depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature ponderosa, Jeffrey and sugar pine are susceptible to mortality during prescribed burns because of the deep duff and litter that has accumulated at their base in the absence of fire. These duff mounds typically burn at a slow rate, while maintaining lethal temperatures, causing severe cambium injury. To protect individual large diameter pine from lethal cambium injury, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

White fir occurring in nearly pure stands tend to have very high levels of course woody debris on the forest floor as a result of downed logs from self-thinning, the continual shedding of branches and the remaining stems from old stands of brush that have been overtopped and killed by dense fir canopies. These types of stands produce tremendous amounts of heat on the ground surface and often cause severe injuries to the boles and crowns of standing trees, especially to smaller diameter trees. If high post-burn mortality levels in true fir stands, resulting in openings and possibly additional heavy fuel loading, is not an acceptable condition, then fuel treatments such as hand or tractor piling should be considered prior to or in place of prescribed fire. This is especially important in roadside units due to the potential for some fire-injured true fir to deteriorate into an unstable and hazardous condition.

Considerations for hazard trees within Reading Fire and along Highway 44 corridor

The Reading Fire burned at low to moderate severity within many stands that contained a high proportion of white fir. Trees that have survived their fire injuries and appear to be growing well may still be in a hazardous condition due to extensive cambium kill and subsequent basal decay. Evaluations of trees within striking distance of a road should include an assessment of fire-injuries that may have resulted in extensive decay. Evidence of dead cambium and/or decay in true fir that extends around more than 1/3 of the bole circumference would indicate high failure potential (Angwin et al 2012).

True fir stands that border Highway 44, in the area just east of Ashpan Snowmobile Part to the north entrance to Lassen Volcanic NP have a long history of mortality and failure due to Heterobasidion root disease infections. Treatments within this corridor, where trees are within striking distance of the highway, should follow Region 5 hazard tree guidelines (Angwin et al 2012) to remove trees with high and moderate failure potential related to root disease infection. In addition, true fir areas with the highest infection levels would benefit from a major effort to convert species composition to non-hosts such as pine species. This includes removing all susceptible host trees from root disease centers and replanting to non-host species.

Potential for funding through the Western Bark Beetle Program

Forest Health Protection may be able to assist with funding, including NEPA activities, for thinning within the Badger project area. Thinning treatments that reduce stand density and change species compositions sufficient to lower the risk to bark beetle-caused mortality would meet the minimum requirements for Western Bark Beetle Program funding and would be supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

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Forest Health Protection, Regional Office

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Insect and Disease Information

Jeffrey pine beetle

The Jeffrey pine beetle is the principle bark beetle found attacking Jeffrey pine, which is its only host. It is a native insect occurring from southwestern Oregon southward through California and western Nevada to northern Mexico. The beetle normally breeds in slow-growing, stressed trees. The beetles prefer trees which are large, mature, and occur singly rather than in groups. Yet when an epidemic occurs, the beetle may attack and kill groups of trees greater than 8 inches in diameter, regardless of age or vigor. Often the beetle infests lightning-struck or wind-thrown trees, but does not breed in slash.

Evidence of Attack
Presence of the beetle is usually detected when the foliage changes color. The color change of the foliage is related to the destruction of the cambium layer by the beetle. Generally, the top of the crown begins to fade in a slow sequence, with the needles turning from greenish yellow, to sorrel, and finally to reddish brown. By the time the tree is reddish brown, the beetles have usually abandoned the tree. Another sign of beetle attack is large, reddish pitch tubes projecting from the bark of the infested tree. If examined carefully, pitch tubes can be detected on infested green trees prior to crown fade. Jeffrey pine beetles have a distinctive "J" shape egg gallery pattern on the inner bark. Larval mines extend across the grain and end in open, oval-shaped pupal cells.

Life Stages and Development
The Jeffrey pine beetle is one of the larger pine bark beetles in California. The beetle has a 4 life stages, egg, larva, pupa, and adult. The adults are stout, cylindrical, black, and approximately five-sixteenths of an inch long when mature. The egg is oval and pearly-white. The larva is white, legless, and has a yellow head. The pupa is also white but is slightly smaller than the mature larva. The life cycle is normally completed in one year in the northern part of the range, but in the southern part, two generations per year may occur. The principle period of attack is in June and July, but attacks also are frequent in late September and early October. Similar to other *Dendroctonus* species, Jeffrey pine beetles use pheromones that attract other beetles to a tree, causing a mass attack that tends to overcome the tree's natural resistance. Blue stain fungi are associated with Jeffrey pine beetle attacks and aid in overcoming the tree’s defenses.

Conditions Affecting Outbreaks
Normally the Jeffrey pine beetle is kept in check by its natural enemies, climatic factors and the resistance of its host. Similar to other *Dendroctonus* species, the availability of suitable host material is a key factor influencing outbreaks. Healthy trees ordinarily produce abundant amounts of resin, which pitches out attacking beetles. When deprived of moisture, or stressed by other factors such as disease or fire injury, trees cannot produce sufficient resin flow and become susceptible to successful beetle attacks

Western Pine Beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensivly studied and has proven to be an important factor in the ecology and management of ponderosa pine thoughout the range of the host species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches DBH. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latidude and elevation, there can be from one to four generations per year.

Evidence of Attack

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. Successful pitch tubes are red-brown masses of resin and boring dust. Relativly few, widely scattered white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheremones released during a successful attack attract other conspecifics. Attracted beetles may then spill over into nearby apparently healthy trees and overwhelm the tree with sheer numbers.

Life Stages and Development

These beetles pass thorugh the egg, larval, pupal and adult stages during a life cycle that varies in length dependent primarily on temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem then mine into the middle bark where they complete most of their development. Bluestain fungi inoculates the tree during successful attacks, blocking trachids and vessicles which contribute to the rapid tree mortality associated with bark beetle attacks.

Conditions affecting Outbreaks

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the Westsince 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles.Information from surveys conducted in the 1930's indicated enormous losses attributed to the western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size though successive beetle generation as is typical with Mountain Pine Beetle and Jeffreay Pine Beetle. Rather, observations indicate that emerging beetles tend to leave the group kill area to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing western pine beetle outbreaks. When healthy trees undergo a sudden and sever moisture stress populations of western pine beetle are likely to increase. Healthy trees ordinarily produce abundant resin, which pitch out attacking beetles, but when deprived of moisture, stressed trees cannot produce sufficient resin to resist the attack. Any condition that results in excessive demand for moisture, such as inter-tree completion, competing vegetation, or protracted drought periods; or any condition that reduces the ability of the roots to supply water to the tree, such as mechanical damage, root disease or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predacious beetles, and low temperatures act as natural control agents when beetle populations are low (endemic populations).

Fir engraver beetle

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater than 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees

defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development
In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year; however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks
Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Mountain pine beetle

The mountain pine beetle, *Dendroctonus ponderosae,* attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

Evidence of Attack

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. In addition to pitch tubes, successfully infested trees will have dry boring dust in the bark crevices and around the base of the tree. Attacking beetles carry the spores of blue-staining fungi which develop and spread throughout the sapwood interrupting the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the needles to discolor and the tree to die.

Life Stages and Development

The beetle develops through four stages: egg, larva, pupa and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is typical, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones. These pheromones attract males and other

females until a mass attack overcomes the tree. The adults bore long, vertical, egg galleries and lay eggs in niches along the sides of the gallery. The larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

Conditions Affecting Outbreaks

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with thick phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include nematodes, woodpeckers, and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and pine mortality increases.

Heterobasidion root disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species:
Heterobasidion occidentale (also called the 'S' type) and *H. irregulare* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* (‘P’ type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* (‘S’ type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of

stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf mistletoe

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

White pine blister rust

White pine blister rust is caused by *Cronartium ribicola* an obligate parasite that attacks 5-needled pines and several species of *Ribes* spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes* spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other *Ribes* spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* spp. leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes* spp., its spread from *Ribes* spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.

Elytroderma needle cast

Elytroderma needle cast caused by *Elytroderma deformans mainly infects* ponderosa and Jeffrey pines but is also found on Coulter, knobcone, lodgepole and pinyon pines. The disease has reached epidemic proportions in certain specific environments, such as around lakes and along stream bottoms. Its concentration around lakes such as Lake Tahoe has considerable effect on the appearance of high-value recreational sites because of defoliation and tree death. Diagnostic symptoms include reddening of needles in the spring, compact globose witches' brooms, with ends tending to turn upward (easily confused with dwarf mistletoe brooms), brown necrotic flecks in the inner bark of infected twigs, and fruiting bodies of the fungus are elongate, narrow, dull black structures(hysterothecia), which can often, but not always, be found on needles; growing on all needle surfaces. Trees infected by *E. deformans* exhibit branch "flags" in spring. These are conspicuous clumps of reddened, dead one-year-old needles with green, current season's foliage at the tip.

Spores are released in late summer and early fall from fruiting bodies (hysterothecia) borne on infected needles. The spores are carried by wind to current-year needles. Under proper microclimatic conditions, the spores germinate and infect these needles, which do not die until the following year. Unlike other needle pathogens, this fungus spreads throughout the needles and into the twigs. It can then spread further into growing tips and buds, infecting and deforming new growth. The microclimatic conditions favorable to infection are not well understood; however, certain areas, such as around lakes and along stream bottoms, appear to be more favorable to repeated infection.

Elytroderma disease is the most important needle cast disease of ponderosa and Jeffrey pines in western North America. It is most severe on seedlings, saplings, and poles with poor crowns. This fungus causes the premature death of 1-yearold needles and a brooming and deformation of infected twigs and branches. The effect of the disease depends on the proportion of the host's crown that is diseased. There is little effect upon the host until more than two-fifths of the twigs are blighted. Although this disease directly kills mature trees only infrequently, moderated to severe infection reduces growth and vigor and thus predisposes the host to other diseases and to bark beetle attack. Studies have shown reductions in radial growth up to 30 percent in trees with more than 50 percent of the foliage showing symptoms.

In forest stands, control of elytroderma disease is rarely necessary or economical. In high-value stands, maintain proper stocking and eliminate trees of low vigor. Trees with *E. deformans*-caused branch flagging or witches' brooms within 6 feet of their leaders should be discriminated against during harvest treatments. Offsite pine plantings should be avoided. Define high-risk areas following disease outbreaks, and regenerate with non-susceptible species.